

SITE CHARACTERIZATION AND MONITORING OF TECHNICAL AREA 49 AT THE LOS ALAMOS NATIONAL LABORATORY

D.G. Levitt, K.C. Kisiel, D.L. Newell
Science and Engineering Associates, Inc.
3205 Richards Lane, Suite A, Santa Fe, NM 87507

J.K. Hopkins, C.W. Criswell
Risk Reduction and Environmental Stewardship-Remediation Program
Los Alamos National Laboratory
PO Box 1663, Mail Stop:M992, Los Alamos, NM 87544

L. A. Woodworth
Department of Energy
Office of Los Alamos Site Operations, Los Alamos, NM 87544

ABSTRACT

In 1959-1961, subcritical hydronuclear safety experiments were conducted at Technical Area (TA) 49 at the Los Alamos National Laboratory (LANL). These underground experiments were designed and conducted to investigate safety issues. Seventy hydronuclear safety, tracer, and containment test experiments were conducted in 1-m or 2-m diameter shafts at depths ranging between 9 m and 33 m. The subsurface radiological and metals inventory consists of about 40 kg of plutonium, 93 kg of uranium-235, 170 kg of uranium-238, 11 kg of beryllium, and possibly more than 90,000 kg of lead. Explosives used in the experiments consisted largely of TNT, RDX, HMX, and barium nitrate. It is highly likely that the explosives, except for the barium component, were completely consumed by the detonations. Hydronuclear safety test shafts were drilled, test materials were placed at the bottom of the shafts, shafts were backfilled with sand or local crushed tuff, tests were detonated, subsidence in the shafts were backfilled, and cement caps were poured over the test shafts. The diameter of the affected detonation zones is believed to be less than 6 m. Most test shafts were drilled on an 8-m grid spacing in four main areas within TA-49.

A variety of investigations and activities have occurred to partially complete site characterization of the surface soils and subsurface soils and rock at TA-49. Some investigations yielded sporadic low-level detections above background values of radionuclides and inorganic constituents at TA-49. The source of this contamination was likely due to one event in 1960 in which transuranic materials were encountered from an adjacent used test shaft while drilling a new test shaft that resulted in contamination being spread around the surface soils of the area. This area of contamination, referred to as Area 2, was covered with an asphalt pad in 1961 to contain this contamination. Years later, it was discovered that the asphalt pad had affected the water balance of Area 2 by allowing infiltration through cracks and a collapsed area of the pad, and by greatly reducing evapotranspiration (ET). In 1998, the cracked asphalt cover was removed and replaced with an ET monolayer cover with an automated soil-moisture monitoring system using time-domain reflectometry (TDR) probes. Soil moisture monitoring data to date indicate that the ET cover is performing well at returning infiltrating precipitation and snowmelt

to the atmosphere by ET, and preventing deep percolation and possible mobilization of contaminants to the regional groundwater aquifer located at a depth of about 366 m below ground surface.

In 2003, six angled boreholes will be drilled under and within about 6 m of the detonation zones of the test shafts, and drill core will be collected to determine if contamination has migrated away from the detonation zones. These uncased shafts will likely remain open following site characterization for monitoring purposes. Moisture content may be monitored using a neutron probe, or using an inverted membrane technique (FLUTETM) that seals and presses downhole sensors against the exposed borehole wall. In addition to drilling boreholes, a detailed radiological screening and sampling survey will be conducted to locate and remediate any contamination that may remain in the surface soils at TA-49.

BACKGROUND

Before 1959, LANL scientists had recognized there were potential safety problems. Underground experiments were designed and conducted to assess this potential problem. The experiments received the approval in late 1959 from President Eisenhower and in early 1960 from President Kennedy. In the fall of 1959, TA-49 was created, and underground experiments were conducted through August 1961 (1).

An unusual aspect of the hydronuclear safety experiments is that the use of special nuclear materials required extremely close accounting of the quantities of uranium, plutonium, lead and beryllium. The quantities and locations of these contaminants are thus known with an unusually high degree of precision. Based on the detailed historical information available, it is evident that other chemicals were used in very limited quantities at TA-49 and no documented evidence or other indication of the presence of other chemical components has been noted (2).

TA-49 was used from 1959 to 1961 for underground hydronuclear safety test experiments. Seventy hydronuclear safety, tracer, and containment test experiments were conducted in 1-m or 2-m diameter shafts at depths ranging between 9 m and 33 m. The area within TA-49 where the test experiments were conducted is now referred to as Material Disposal Area (MDA) AB. The areas within MDA AB where the underground experiments were conducted are referred to as Areas 1, 2, 2A, 2B, 3, and 4 (2). These Areas are also referred to as Potential Release Sites (PRSs). Refer to Fig. 1 for the location of TA-49 and LANL within New Mexico, and refer to Fig. 2 for the locations of Areas and PRSs within TA-49. Table I provides a subsurface radionuclide inventory from MDA AB, and the correlation between Area and PRS designations within MDA AB at TA-49.

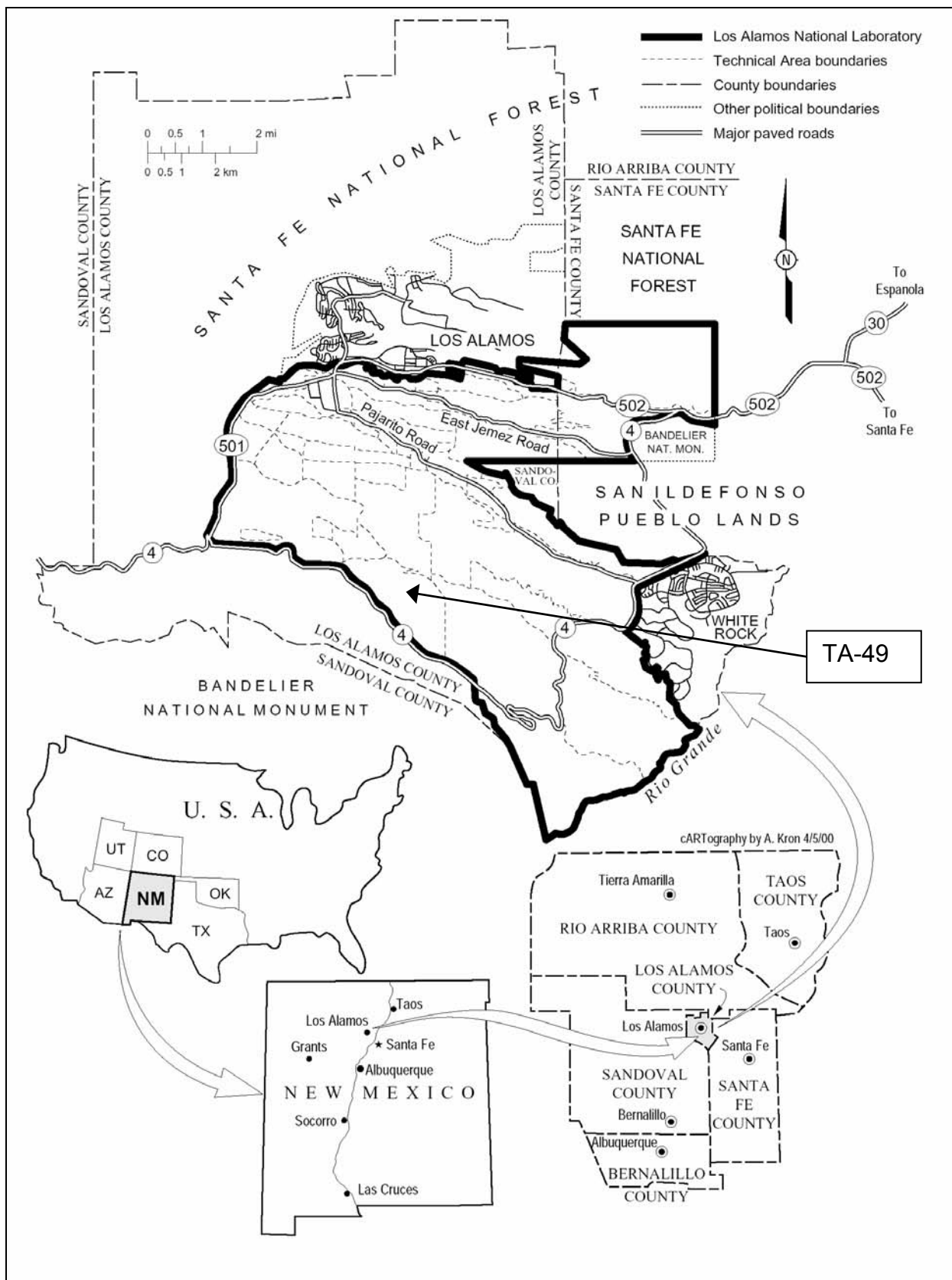


Fig. 1. Location of the Los Alamos National Laboratory and TA-49.

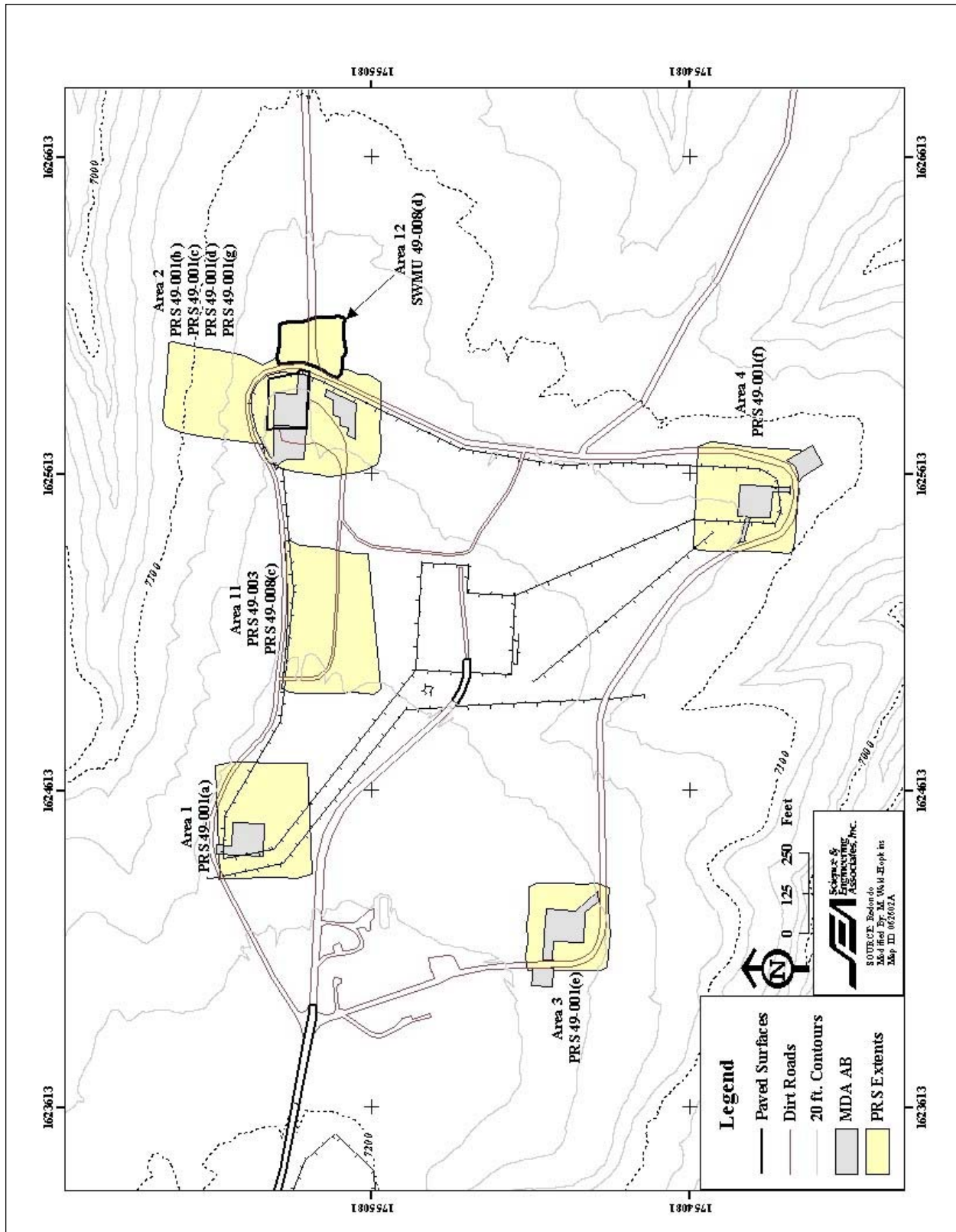


Fig. 2. Locations of Areas and PRSs within TA-49 at LANL.

The subsurface radiological and metals inventory consists of about 40 kg of plutonium, 93 kg of uranium-235, 170 kg of uranium-238, 11 kg of beryllium, and possibly more than 90,000 kg of lead. MDA AB is estimated to contain over 80% of the LANL's inventory of buried transuranic material by radioactivity content. Explosives used in the experiments consisted largely of TNT, RDX, HMX, and barium nitrate. It is highly likely that the explosives, except for the barium component, were completely consumed by the detonations. Hydronuclear safety test shafts were drilled, test materials were placed at the bottom of the shafts, shafts were backfilled with sand or local crushed tuff, tests were detonated, subsidence in the shafts were backfilled, and cement caps were poured over the test shafts. The diameter of the affected detonation zones is believed to be less than 6 m. Test shafts were drilled on an 8-m square grid spacing in Areas 1, 2, 3, and 4, but grid spacing was irregular in Areas 2A and 2B (2).

Table I. Subsurface Radionuclide Inventory of MDA AB and Correlations between Areas and Potential Release Site Designations

MDA AB Area	PRS Name	Pu (kg)	U-235 (kg)	U-238 (kg)
Area 1	49-001 (a)	1.06	0.00	62.3
Area 2	49-001 (b)	12.62	47.4	52.5
Area 2A	49-001 (c)	3.75	9.8	10.6
Area 2B	49-001 (d)	5.67	6.4	14.7
Area 2 Total:		22.04	63.60	77.80
Area 3	49-001 (e)	0.000	0.005	0.030
Area 4	49-001 (f)	17.04	29.4	29.0

Since 1992, a variety of investigations and activities have occurred to partially complete site characterization of the surface soils and subsurface soils and rock at MDA AB. Some investigations yielded sporadic low-level detections above background values of radionuclides and inorganic constituents. The source of most of the surface contamination is suspected to be the result of one event in 1960 in which transuranic materials were encountered from an adjacent used test shaft while drilling a new test shaft that resulted in contamination being spread around the surface soils of the area. This area of contamination, in the center of Area 2 (see Fig. 2), was covered with an asphalt cover in 1961 to contain this contamination (2).

In 1975, many cracks and a large collapsed area (1.8 by 0.9 m wide and 0.9 to 1.2 m deep) of the asphalt cover were discovered. It was also discovered that Core-Hole 2 (CH-2), a 5-cm diameter, 152-m deep cased borehole (originally drilled for hydrogeologic characterization) located in the center of Area 2 (see Fig. 2.) contained about 15-m of standing water. It was suspected that the cracks and collapsed area in the asphalt cover allowed focused infiltration of water through contaminated buried soil and into CH-2. Analysis of the standing water in CH-2 revealed detectable but low-level concentrations of plutonium. In 1976, the asphalt cover was repaired, but more cracks and standing water were again found in CH-2 in 1979, 1980, and 1991.

In 1994, LANL conducted a subsurface Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) at Area 2, and a surface RFI throughout MDA AB (see Fig. 2). For the subsurface RFI at Area 2, seven boreholes (four shallow and three deep) were drilled for hydrogeologic characterization, and for determination of nature and extent of contamination.

Four 3-m deep boreholes were backfilled immediately after drilling and sample collection were completed. Two 46-m deep boreholes and one 213-m deep borehole were cased and left open for monitoring purposes. The 213-m deep borehole was drilled approximately 30-m to the southeast of the boundary of Area 2, while the other six boreholes were drilled through the asphalt cover on Area 2. Contamination was found in some surface soil samples, with sporadic low-level detections in the subsurface. Samples collected from the 46-m deep boreholes did not contain any transuranic materials from the hydronuclear tests, indicating that the experiment blast zone did not extend beyond a 7-m distance.

The subsurface RFI yielded sporadic detections of radioactive contamination. The sample with the highest detected activity was a soil sample from a depth of 76-91 cm with a concentration of 167 pCi/g plutonium-239. A total of approximately nine subsurface samples had radionuclide detections above background, and all but one (mentioned above) had concentrations less than 5 pCi/g. The only subsurface detections above background of inorganic constituents included seven above-background detections of cadmium, and one above-background detection of beryllium and chromium. All of these detections were slightly higher than their background values.

The surface RFI for MDA AB also yielded sporadic detections of radioactive and inorganic contamination. However, all detections were considerably less than screening action levels. The sample with the highest detected activity was a soil sample from the north of Area 2, with a concentration of 13.7 pCi/g plutonium-239. Other detections of radioactive and inorganic contamination were found in samples collected in Areas 1, 2, and 4. No detections of radioactive contamination were found in surface samples collected in Area 3. Occasional detections of cadmium, zinc, copper, lead, and, nickel were found in surface soils at MDA AB.

The Area 2 asphalt pad remained in place until it was removed during an interim measure (IM) implemented in 1998 at the direction of New Mexico Environment Department Hazardous and Radioactive Materials Bureau. The area was covered with soil and gravel as part of stabilization activities. The IM was conducted to address concerns arising from moisture accumulation beneath the asphalt pad. It had become apparent that the asphalt cover had affected the water balance of Area 2 by allowing focused infiltration through the cracks (and the collapsed area of the cover), and by virtually eliminating ET from the water balance.

In 1998-1999, the IM and associated best management practice activities were conducted at Area 2, including:

- Installation of a run-on diversion channel to the west of Area 2
- Removal of the asphalt cover over Area 2
- Surface regrading of Area 2 to eliminate ponding
- Grouting and abandonment of CH-2 and the two 46-m deep RFI boreholes
- Installation of an ET cover composed of crushed tuff monofill and covered with a steel mesh bio-barrier
- Installation of a silt fence surrounding the ET cover to control both erosion and contaminant transport
- Seeding the ET cover with shallow-rooting grasses.

In May 2000, the Cerro Grande forest fire burned to the west, and just to the north of MDA AB, but did not burn any vegetation or any of the remaining structures at MDA AB. The fire did burn the western and northern edges of TA-49.

COVER MONITORING

ET covers have proven to be extremely effective in the arid and semi-arid western United States in preventing percolation of precipitation into waste zones, and they may perform better than traditional prescriptive covers in many cases (3, 4). An ET cover was installed over the Area 2 test shafts in 1998. In February 2000, a moisture monitoring system was installed to monitor the ET cover. Three shallow (4.6-m deep) neutron logging access tubes were installed through the ET cover, and TDR probes (Campbell Scientific Inc. [CSI], model CS615) at two depths and at two locations (west and east) were installed in the ET cover. The TDR probes were wired into a CSI datalogger for automated measurements. Volumetric water contents are measured with the four TDR probes twice per day. At the west location, TDR probes were buried at depths of 15 and 183 cm. At the east location, TDR probes were buried at depths of 15 and 305 cm. At both locations, the shallow probe was buried in a horizontal position while the deep probe was buried in a vertical position. At the west location, the deep probe was buried in soil, while at the east location, the deep probe was buried in the El Cajete pumice layer.

Soil moisture monitoring data provided by neutron logging are shown in Fig. 3. These neutron logging data indicate that the ET cover is performing well and generally maintaining ambient water content levels at between 10 and 20 percent volumetric water content.

A time-series plot of volumetric water content measured with the four TDR probes, and volumetric water content measured at 183 and 305 cm depths in the two neutron logging access tubes closest to the TDR locations, are shown in Fig. 4. Data from the two shallow TDR probes indicate that the top 15 cm of soil approached saturation during the first winter and spring following installation of the ET cover monitoring system. However, data measured with the two deep TDR probes, and by neutron probe indicate that wetting fronts did not infiltrate to depths of 183 and 305 cm. In the winter and spring of 2002, no infiltration was measured due to a strong drought. Some infiltration was measured with the shallow TDR probes in October 2002.

The TDR and neutron probe data are in good agreement at the west site, but they differ by about 10 percent volumetric water content at the east site. This is likely due the TDR probe and the neutron access tube being in different stratigraphic horizons with different hydraulic properties despite being measured at the same depth.

Soil moisture monitoring data using TDR and neutron logging to date indicate that the ET cover is performing well at returning infiltrating precipitation and snowmelt to the atmosphere by ET, and preventing deep percolation and possible mobilization of contaminants to the regional groundwater aquifer located at a depth of about 366 m below ground surface.

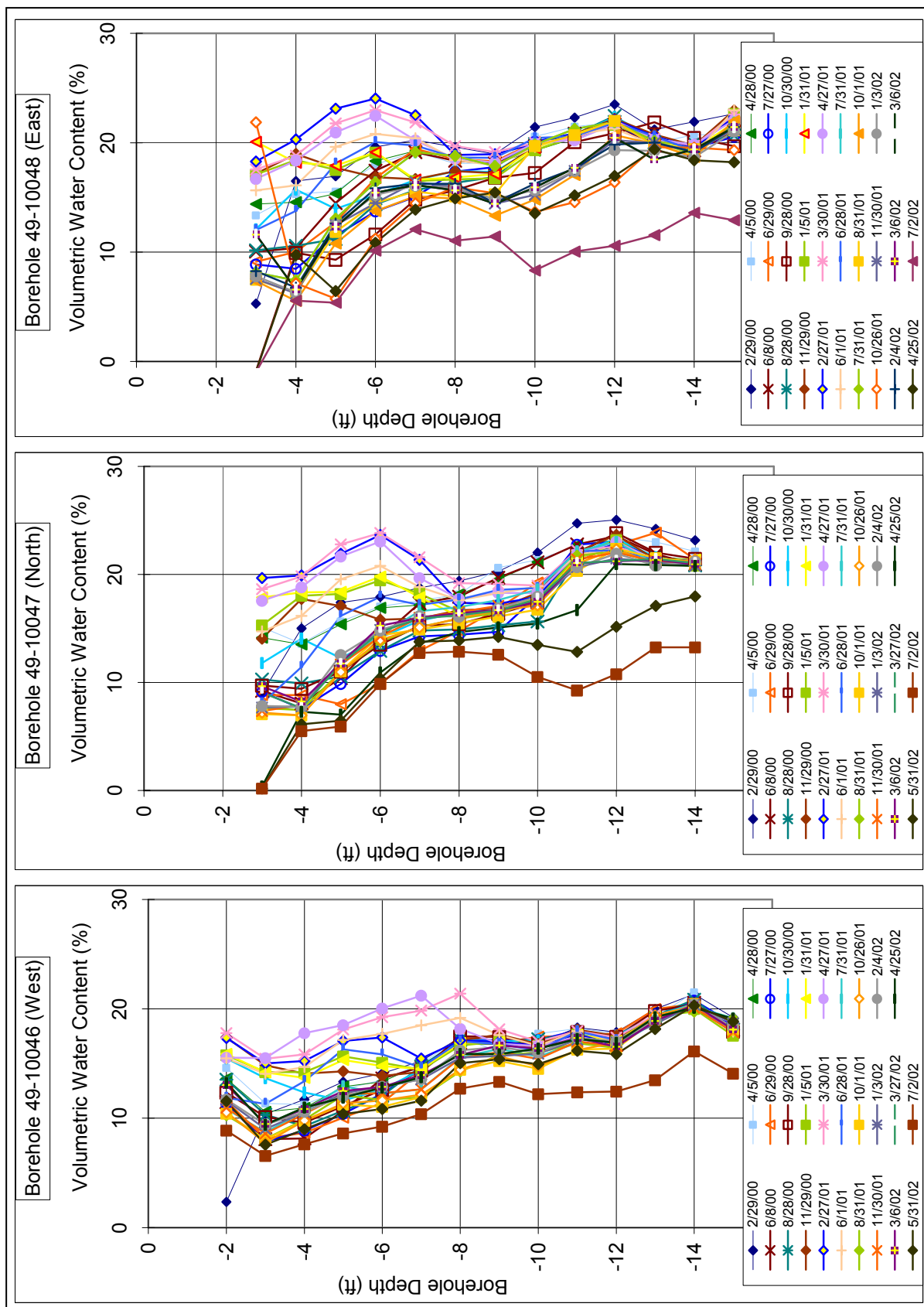


Fig. 3. Volumetric water content measured in the Area 2 ET cover using neutron probe.

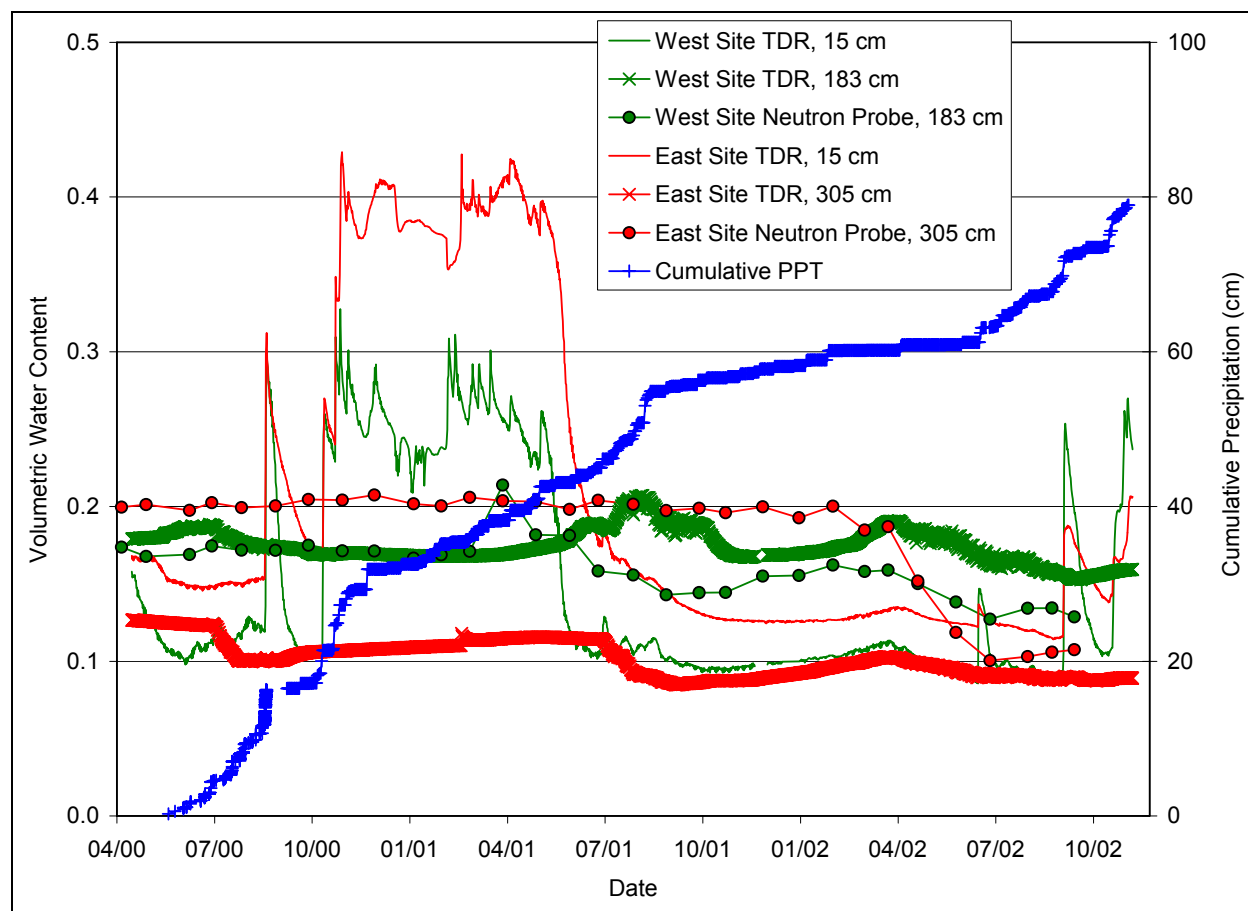


Fig. 4. Volumetric water content measured in the Area 2 ET cover using TDR and neutron probe.

REMAINING CHARACTERIZATION ACTIVITIES

In 2003, six angled boreholes will be drilled under and within about 6 m of the detonation zones of the test shafts, and drill core will be collected to determine if contamination has migrated away from the detonation zones. These uncased shafts will likely remain open following site characterization for monitoring purposes. Moisture content may be monitored using a neutron probe, or using an inverted membrane technique (FLUTE™) that seals and presses downhole sensors against the exposed borehole wall. In addition to drilling boreholes, a detailed radiological screening and sampling survey will be conducted to locate and remediate any contamination that may remain in the surface soils at TA-49.

Five angled boreholes drilled under hydronuclear safety tests at 45 to 66 degrees from horizontal to depths ranging from 26 to 66 m, and one angled borehole drilled at 79 degrees from horizontal to a depth of 168 m, should be sufficient to complete the subsurface characterization and define the extent of subsurface contamination of MDA AB. The steeply-angled, deep borehole will be drilled 50 m beneath the bottom of CH-2, to investigate if CH-2 provided a preferential pathway for contaminant movement. The proposed angled boreholes will likely provide far more useful

data than the vertical boreholes originally prescribed in the RFI Work Plan (2). The dimensions and purpose for the six angled boreholes planned for drilling in 2003 are summarized in Table II.

Table II. Dimensions and Purpose of Six Proposed Characterization Boreholes

Area	Depth (m)	Length (m)	Angle (deg)	Direction	Purpose
1	25.6	36.3	45	S to N	Characterization of water/contaminant movement & tuff properties
2	41.1	58.2	45	N to S	Characterization of water/contaminant movement & tuff properties
2	167.6	170.7	79	E to W	Detect extent of water/contaminant movement from 2 shots & CH-2, & identify fault zones
3	58.5	64.0	66	N to S	Characterization of water/contaminant movement & tuff properties
4	47.5	67.4	45	W to E	Characterization of water/contaminant movement & tuff properties, & identify fault zones
4	65.8	93.3	45	N to S	Characterization of water/contaminant movement & tuff properties

CONCLUSIONS

Many characterization investigations and remediation activities have been conducted at MDA AB during the past eight years. The results of these investigations indicate that the surface soils at MDA AB are now generally clean and free of radiochemical, inorganic, and organic constituents. However, there likely remain occasional isolated and sporadic hits of contamination. A final thorough radiological field screening survey, in association with surface sampling, will be conducted in an attempt to locate and remove any remaining contamination in the surface soils.

Data from the site characterization investigations of MDA AB, when complete, will provide direction for a decision on the closure strategies for Areas 1, 3, and 4 within MDA AB. Possible closure strategies include No Further Action or conducting a Corrective Measures Study such as the installation of ET covers over Areas 1, 3, and 4, if warranted. The remediation strategy of excavating the hydronuclear test shafts in order to retrieve transuranic materials is currently considered to be highly unlikely due to health and safety considerations to workers.

There is no indication that the radionuclide inventory associated with the subsurface hydronuclear safety experiments in MDA AB are migrating due to water flow and associated radionuclide transport. The only site that was subjected to enhanced infiltration conditions at MDA AB was the Area 2 asphalt cover which was removed in 1998. Vadose zone monitoring data from the ET cover that replaced the asphalt cover indicate that the cover is performing well at removing infiltrated water from the cover and isolating the radiological inventory located approximately 17 m below the cover. It is important to note that if percolation from precipitation and focused infiltration reached a depth of 17 m while the asphalt cover was in place, that pathway has been eliminated with the installation of the ET cover, and any areas of elevated moisture content at depth should redistribute to drier areas in the subsurface.

Long-term monitoring such as vadose zone monitoring of the ET cover, groundwater monitoring, air monitoring, and sediment (from runoff and erosion) monitoring will likely continue throughout institutional control of LANL to ensure the safety of the public, workers, and the environment.

REFERENCES

1. R. N. THORN and D. R. WESTERVELT, "Hydronuclear Experiments," LANL Report LA-10902-MS, Los Alamos National Laboratory Report (1987).
2. LOS ALAMOS NATIONAL LABORATORY. "RFI Work Plan for Operable Unit 1144," LANL Report LA-UR-92-900, Los Alamos National Laboratory (1992).
3. S. F. DWYER, "Alternative Landfill Cover Pass the Test." Civil Engineering, September (1998).
4. S. F. DWYER, "Finding a Better Cover," Civil Engineering, January (2001).

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.